W and Z Production in the Forward Region at LHC

Müller, K

Abstract: Results are presented on the production of Z $\rightarrow \mu\mu and W \rightarrow \mu\nu in the forward region at LHCb. The analysis is base$
$1. The production cross-section for Z with muons in the pseudorapidity range 2 < \eta\mu < 4.5 and 81 Z < 101 GeV is 74 ś 2 ś 3 ś 7 pb ar$
$section for W production is \sigma W+(2 < \eta < 4.5) = 1007 ś 48 ś 101 pb and \sigma W-(2 < \eta < 4.5) = 680 ś 40 ś 68 pb in the lepton pseudora$
$\eta < 4.5. The charge asymmetry is measured as a function of the lepton pseudorapidity. All results are in agreement with next to$

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W and Z production in the forward region at LHCb

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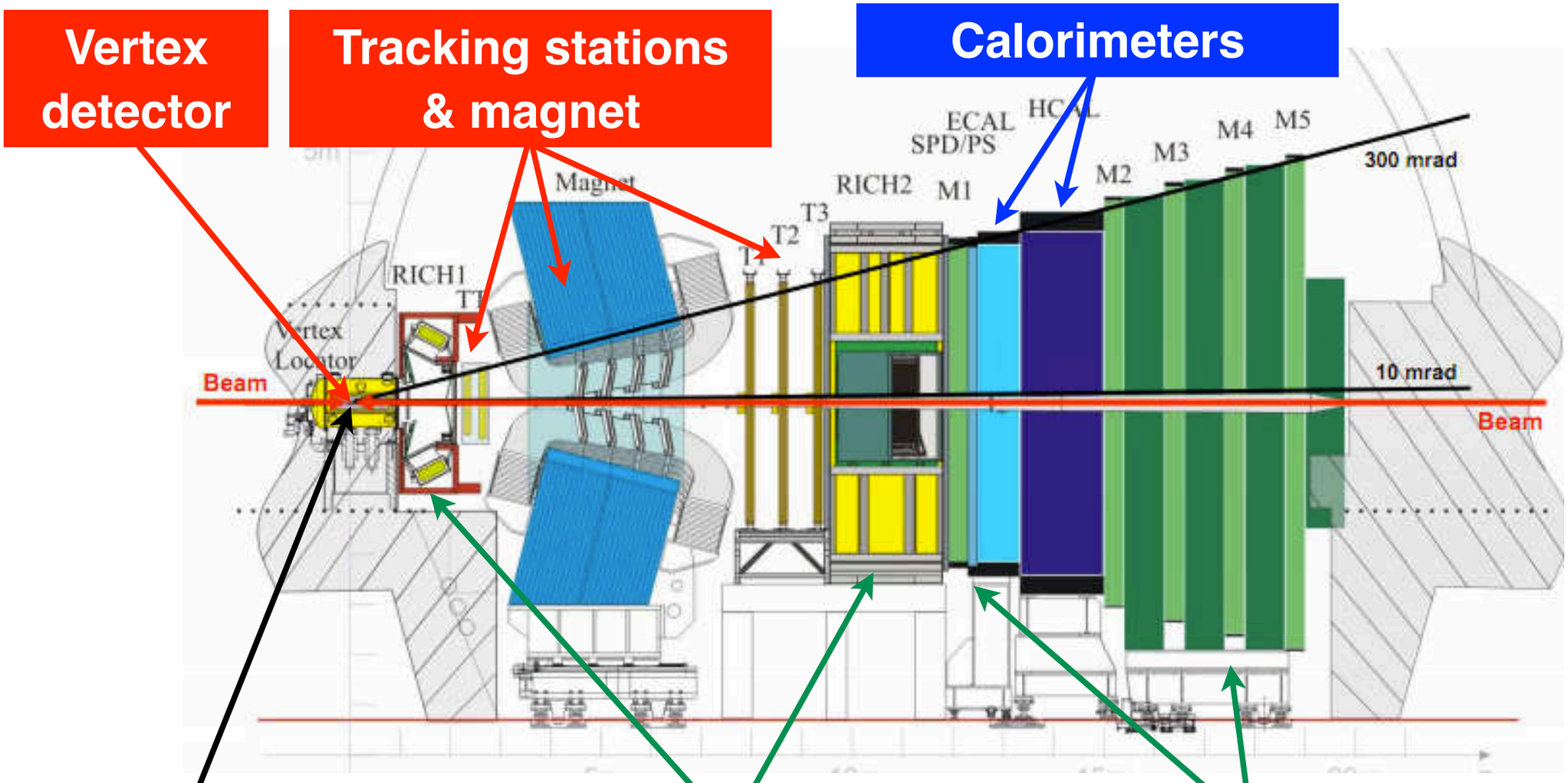
For the LHCb collaboration

LHCb: A forward spectrometer

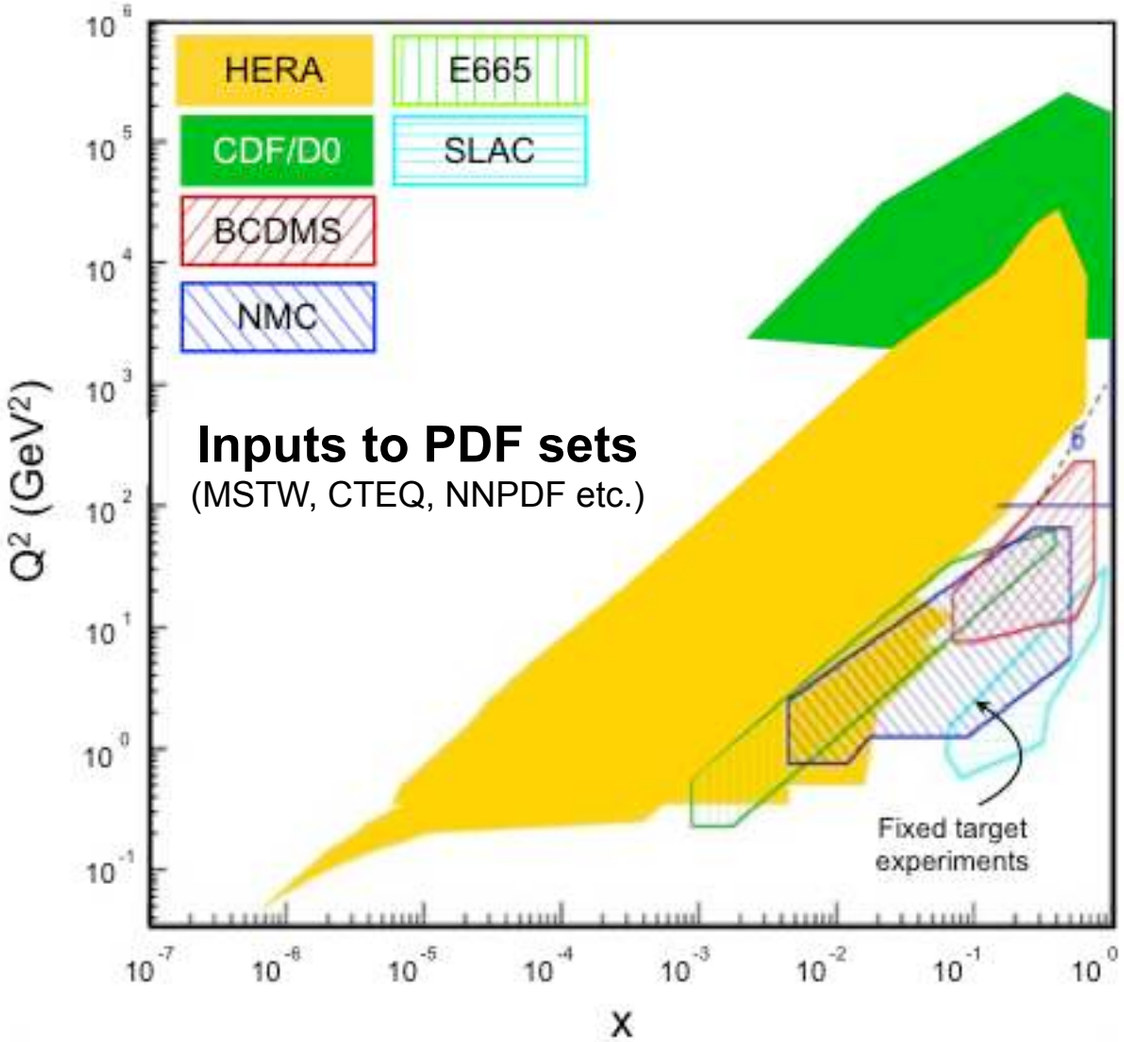
- Designed to search for new physics in B and D decays at LHC
- Fully instrumented in the forward region (1.9 < eta < 4.9)
- Data collected: 37.7 pb^{-1} (2010) and 235 pb^{-1} (2011 so far)
- W and Z measurements with 16.5 pb^{-1} (2010)

Momentum
Particle ID
Energy



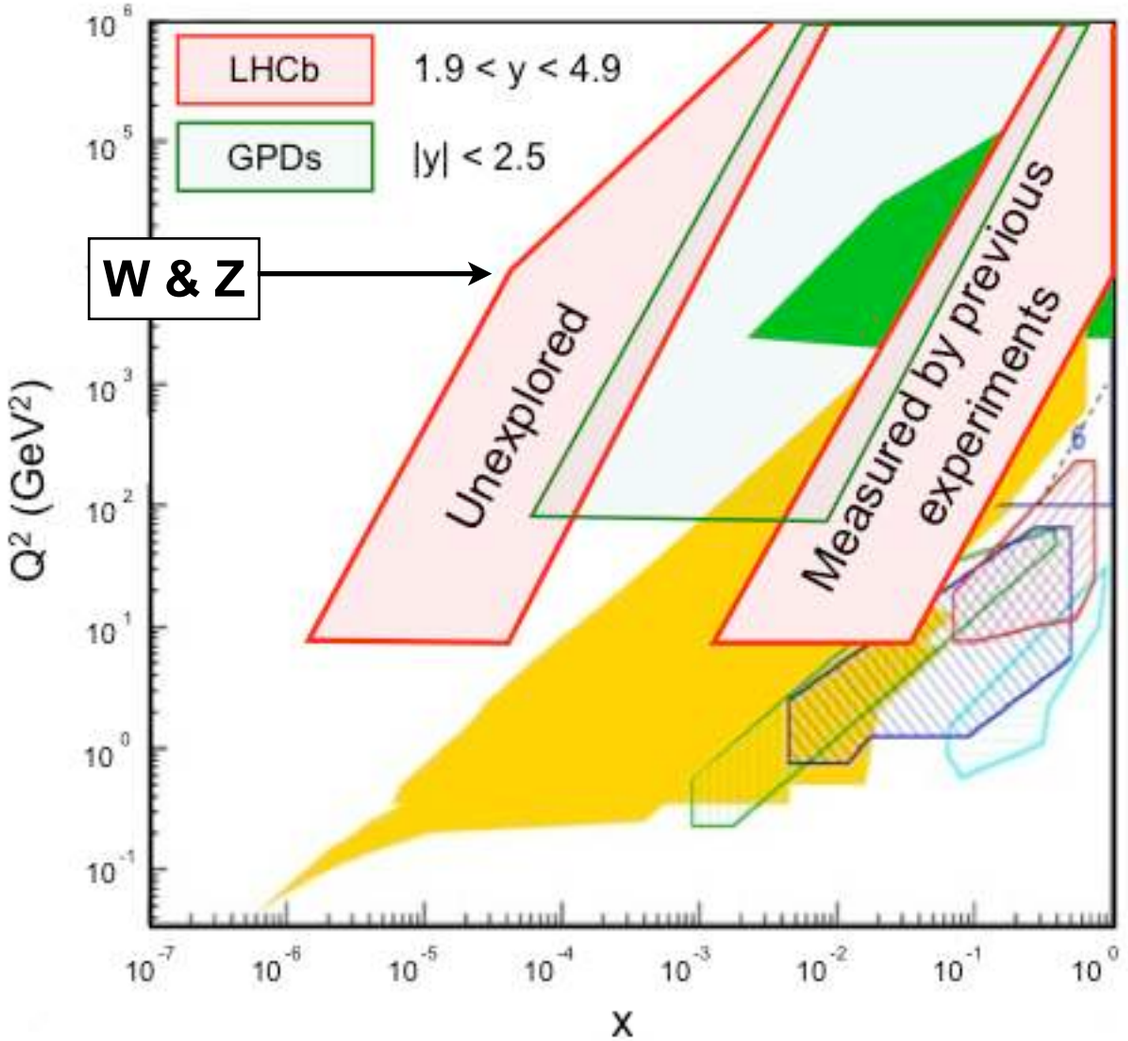
Kinematic reach at LHCb

Current inputs to proton PDFs



Low-x region currently only probed by HERA

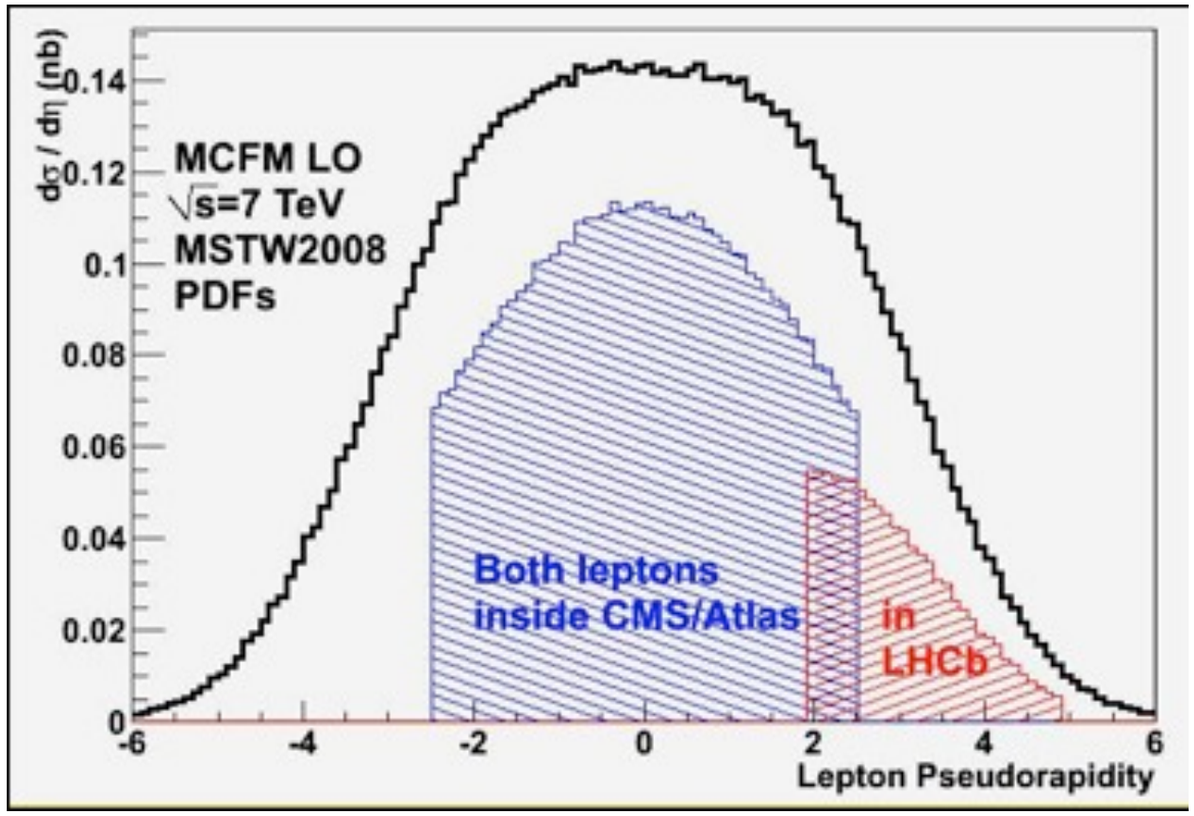
(x,Q²) explored by LHCb



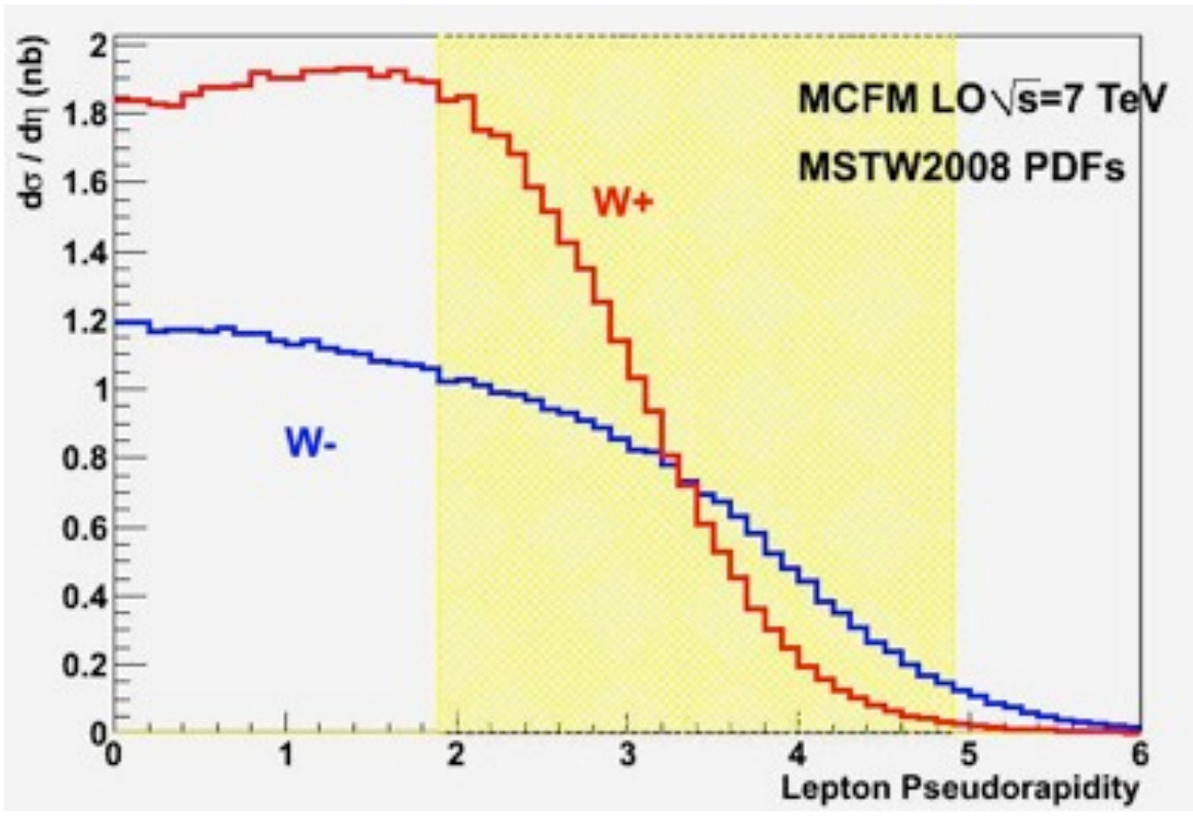
LHCb will probe 2 distinct regions
Low-x region previously unexplored
W & Z: $x_1 = 10^{-1}$ and $x_2 = 10^{-4}$

W and Z production at LHCb

- Complimentary range to ATLAS/CMS
- Overlap region for cross-check
- Crossover point of W asymmetry inside acceptance



8% of Z within LHCb acceptance

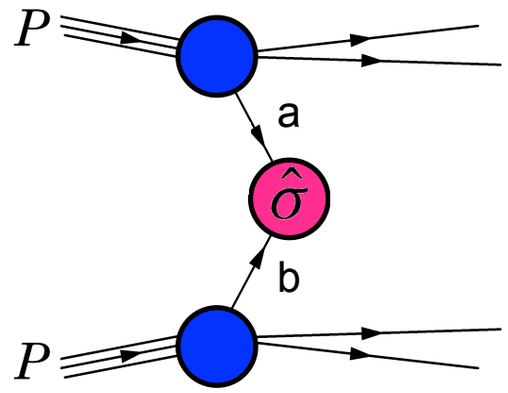


~ 16% of W within LHCb acceptance.

W and Z production at LHCb

$$\sigma_{AB\to X} = \int dx_a dx_b f_{a/A}(x_a, Q^2) f_{b/B}(x_b, Q^2) \hat{\sigma}_{ab\to X}$$

PDFs (from data) **Partonic interaction** (pQCD)

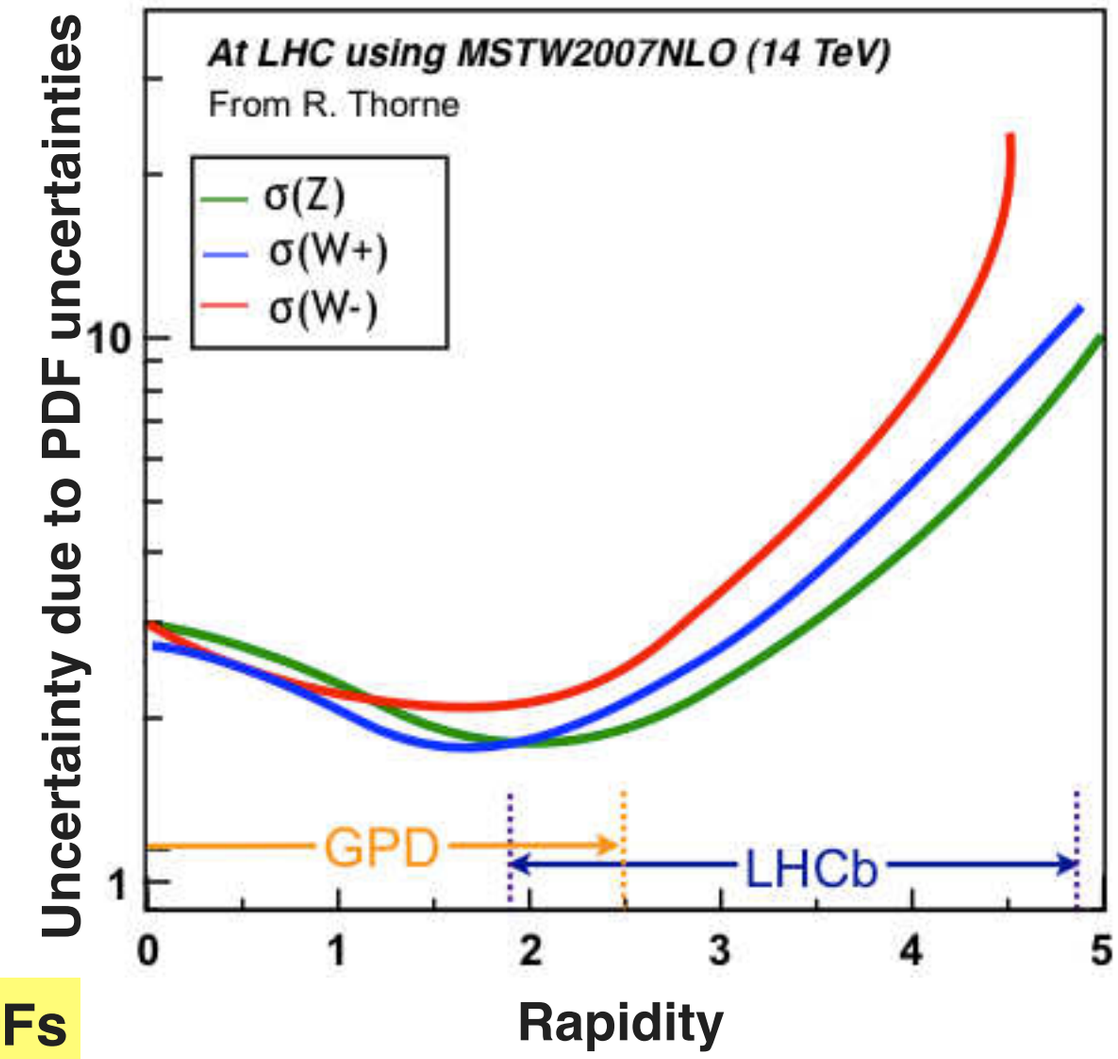


Theoretical predictions

- Factorised calculation (partonic cs & proton pdfs)
- Partonic cross-sections known to 1% (NNLO)
- PDF uncertainties dominate at large rapidities (6-8% at y=5)

Experimental measurements

- Clean signature
- Easily reconstructed final states
- Low systematic uncertainties



W and Z measurements at LHCb will constrain PDFs

W and Z ratios at LHCb

Many experimental uncertainties cancel

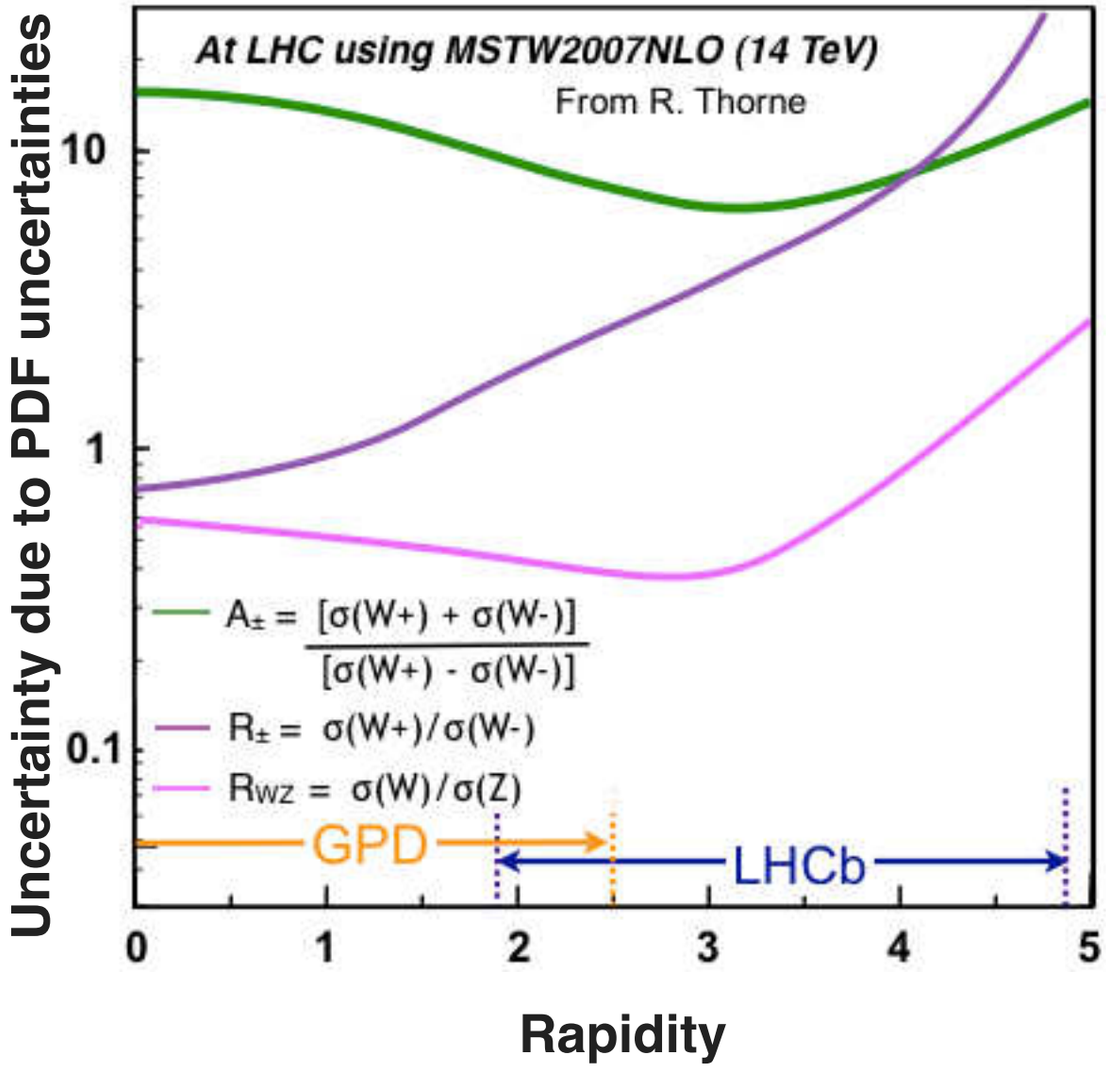
- Luminosity etc.

Cancel or highlight PDF uncertainties with ratios

- **$R_{+-} = d\sigma(W^+)/d\sigma(W^-)$**
  Tests d_v/u_v ratio

- **$A_{+-} = (d\sigma(W^+)-d\sigma(W^-))/(d\sigma(W^+)+d\sigma(W^-))$**
  Tests difference between d_v and u_v

- **$R_{WZ} = d\sigma(W)/d\sigma(Z)$**
  Almost insensitive to PDFs

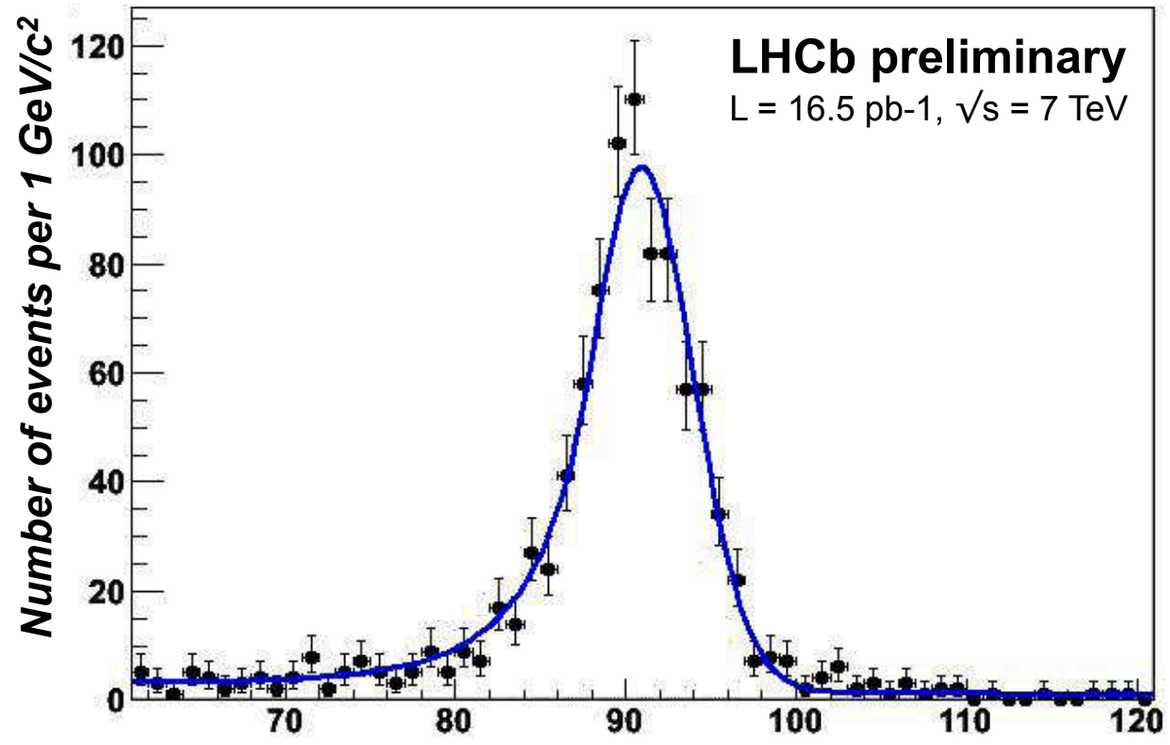


Z cross-section measurement

Trigger: single muon with pT > 10 GeV/c

Offline: 2 reconstructed muons with
- Good track quality
- pT > 20 GeV/c
- 2 < eta < 4.5
- 81 GeV/c^2 < $M_{\mu\mu}$ < 101 GeV/c^2

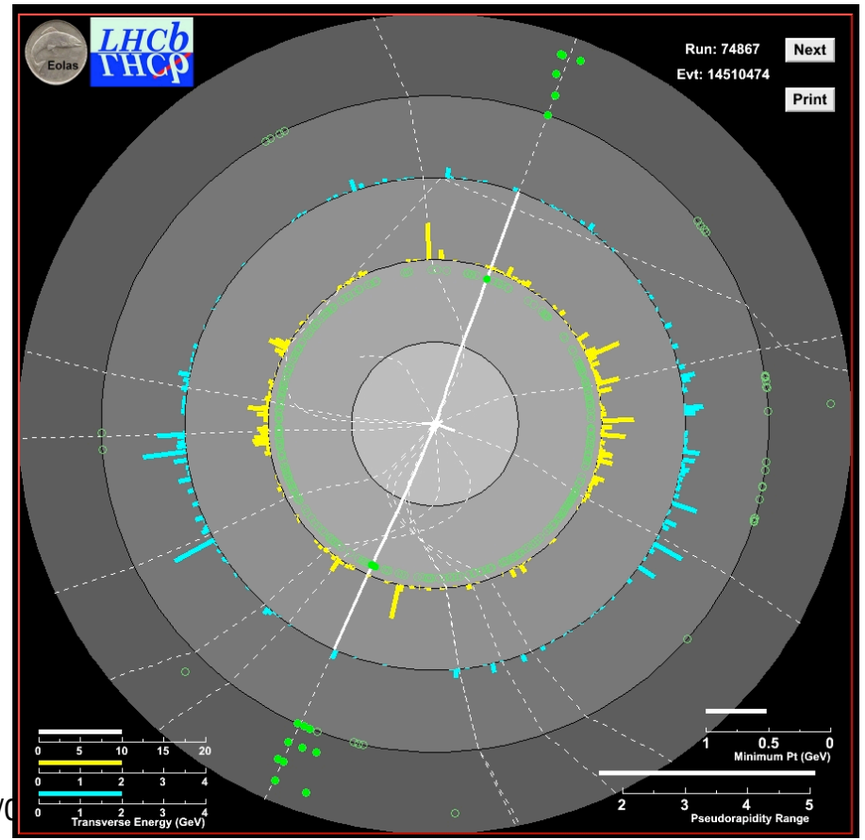
Backgrounds:
- Heavy flavour ~ 1 candidate (data)
- Hadron mis-id ~ 0.03 candidates (data)
- Tauonic Z decays ~ 0.2 candidates (MC)



Preliminary Results with 16.5 pb^{-1}:

$N_{candidates}$ = 833

$N_{background}$ = 1.2 ± 1.2



W cross-section measurement

Trigger: single muon with pT > 10 GeV/c

Offline:

1 reconstructed muon with

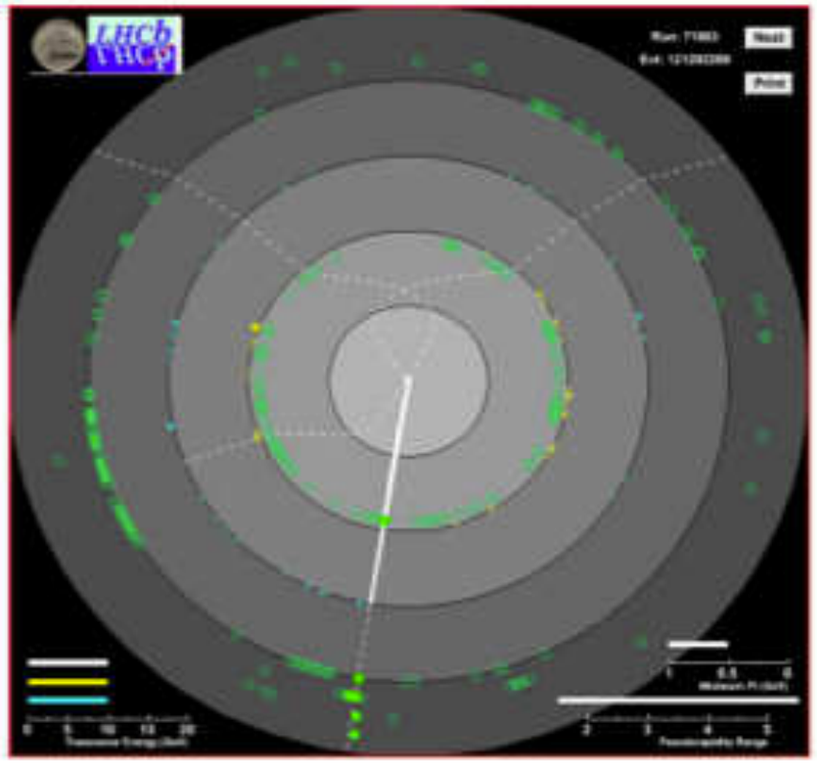
- Good track quality
- pT > 20 GeV/c
- 2 < eta < 4.5
- Impact parameter significance < 2
- Sum pT in cone around muon < 2 GeV/c (R=0.5)

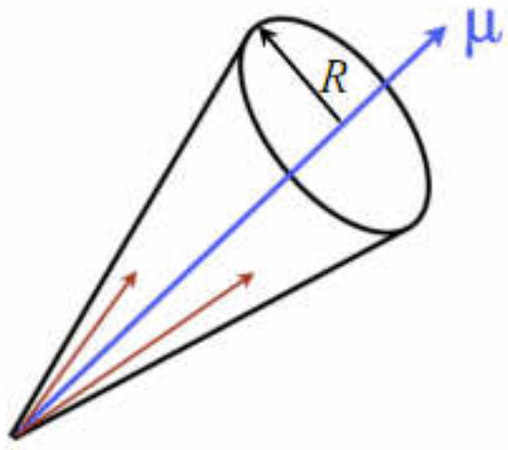
Rest of the event

- Invariant mass < 20 GeV/c2
- Sum pT < 10 GeV/c

Backgrounds:

- QCD backgrounds (data)
- Muonic Z decays (MC & data)
- Tauonic W & Z decays (MC & data)





$$R = \sqrt{\Delta\eta^2 + \Delta\phi^2}$$

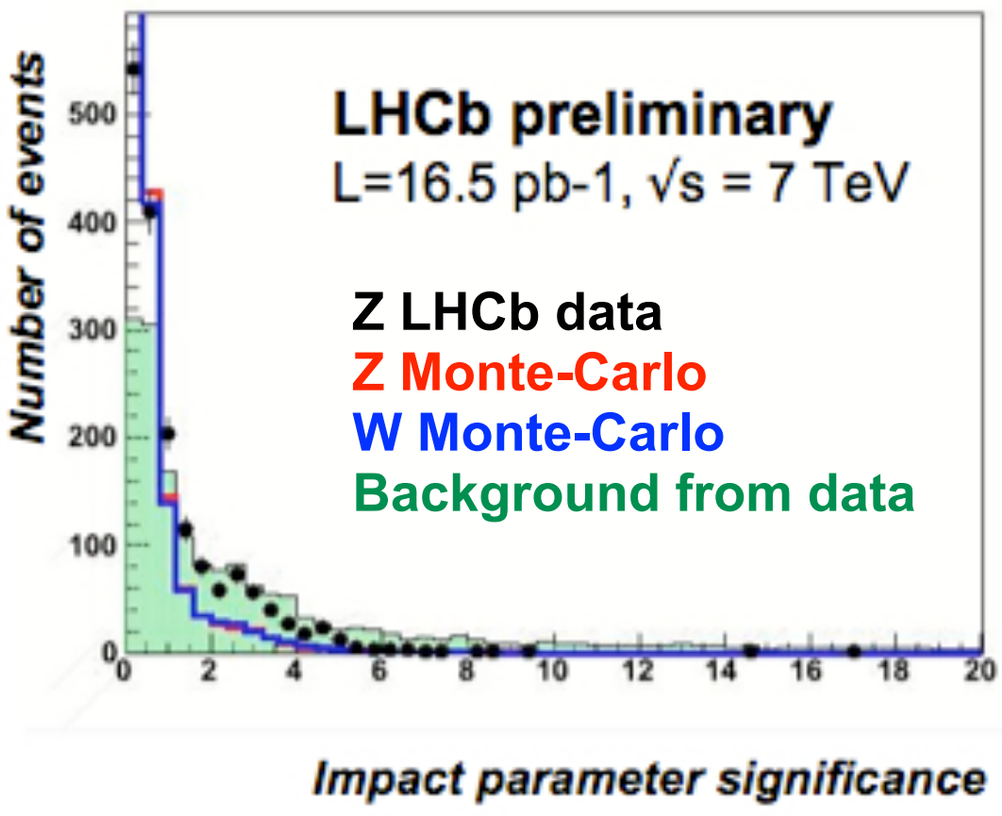
W cross-section measurement

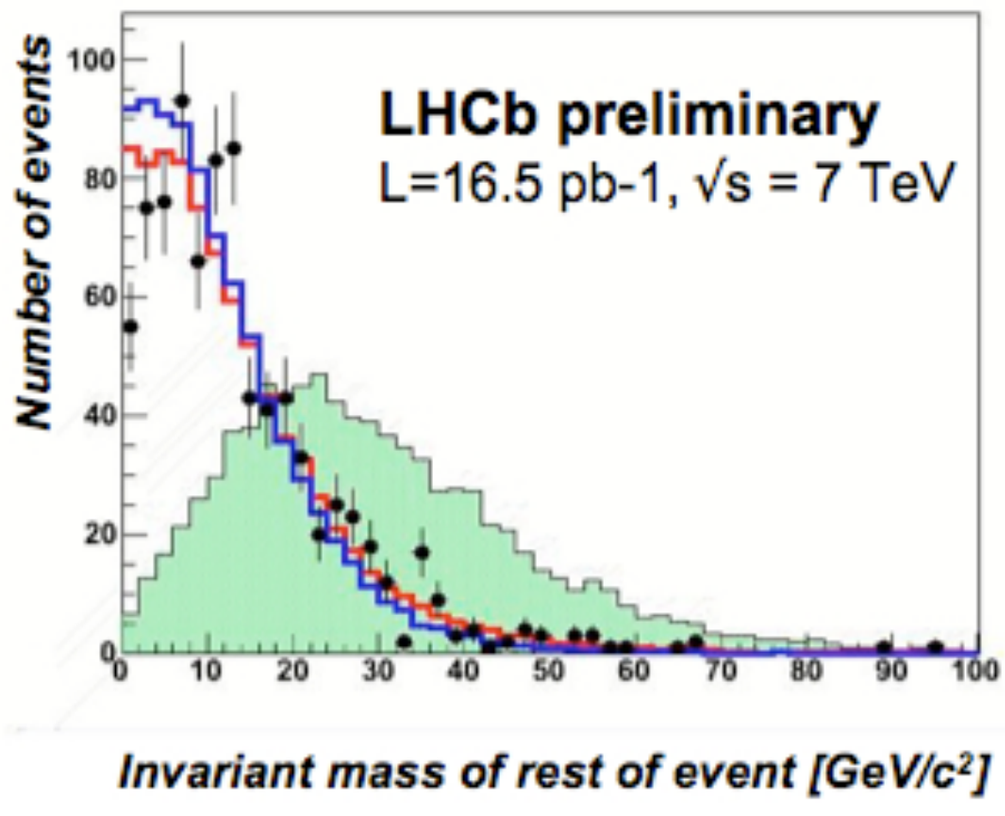
Determination of selection efficiency

- Choice of selection cuts by comparing pseudo-W events from data (Z events with muon removed) and backgrounds from data (anti-cut on other viariables)
- Selection efficiency determined with pseudo-W events from data (eff = (55 ± 1)%
- Cross-checks: W(sim) = Z(sim); Z(sim) ~ Z(data)

Cuts applied:

- Muon IPS < 2
- Event mass < 20 GeV
- Event ∑pT < 10 GeV
- Cone ∑pT < 2 GeV

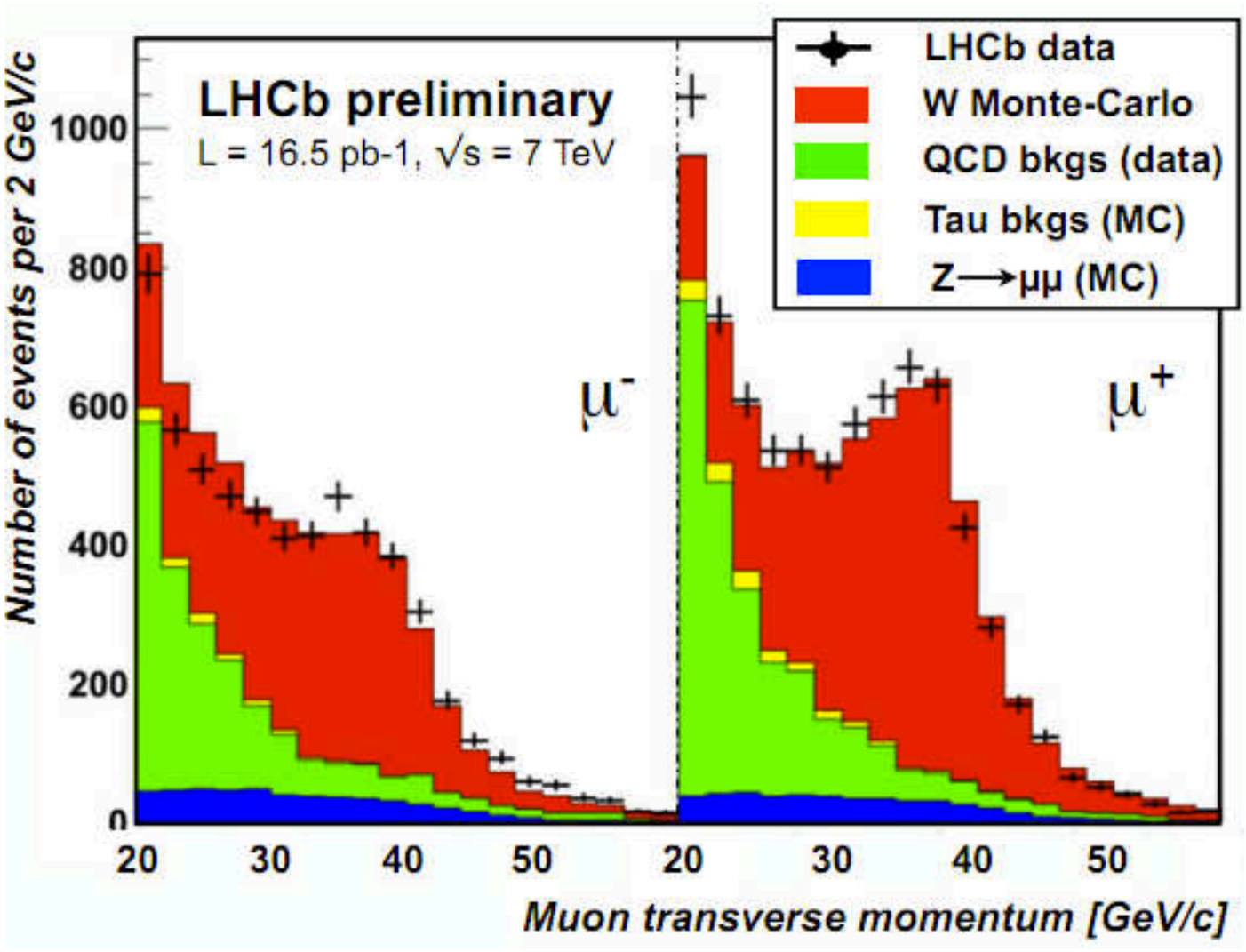




W cross-section measurement

Determination purities

- Fit muon pT spectrum in data to expected shapes for signal and backgrounds (fit is performed in eta bins to obtain differential results)
- QCD background is large and asymmetric



Preliminary Results with 16.5 pb^{-1}:

$N_{candidates}(+) = 7624$

$N_{candidates}(-) = 5732$

$N_{background}(+) = 2194 \pm 150$

$N_{background}(-) = 1654 \pm 150$

Efficiency determination for W & Z measurements

The cross-section can be expressed as:

$$\sigma = \frac{N_{candidates} - N_{bg}}{\varepsilon \cdot \int L}$$

Where ε is the total efficiency and can be expressed as:

$$\varepsilon = A \cdot \varepsilon_{trigger} \cdot \varepsilon_{tracking} \cdot \varepsilon_{\mu-ID} \cdot \varepsilon_{selection}$$

Since we measure inside a limited fiducial volume (pT > 20 GeV/c and 2 < eta < 4.5), A = 1 by definition.

The trigger, tracking and muon ID efficiencies are determined from data and cross-checked against Monte-Carlo (see the following slides)

Trigger efficiency

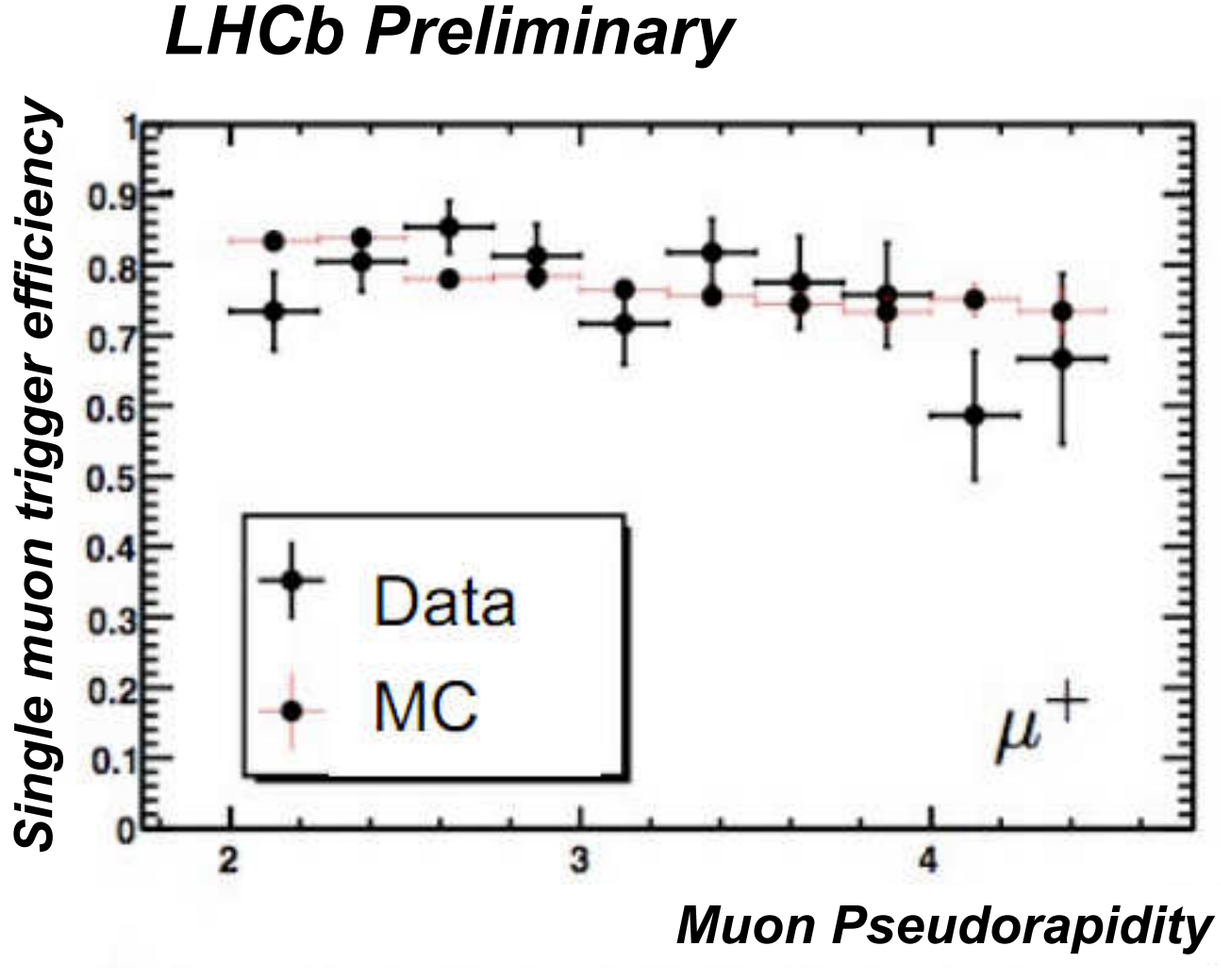
$$\varepsilon_Z = A_Z \varepsilon_Z^{trig} \varepsilon_Z^{track} \varepsilon_Z^{muon} \varepsilon_Z^{selection}$$

Single muon trigger efficiency

- Determine from data using an offline selected Z sample and tag and probe method
  - **Tag:** muon passing single muon line
  - **Probe:** Offline identified muon
- Efficiency given by how often the probe muon passes the single muon line

Efficiency is flat in eta, phi and Pt
No evidence of charge bias

eff = 86 ± 1 %

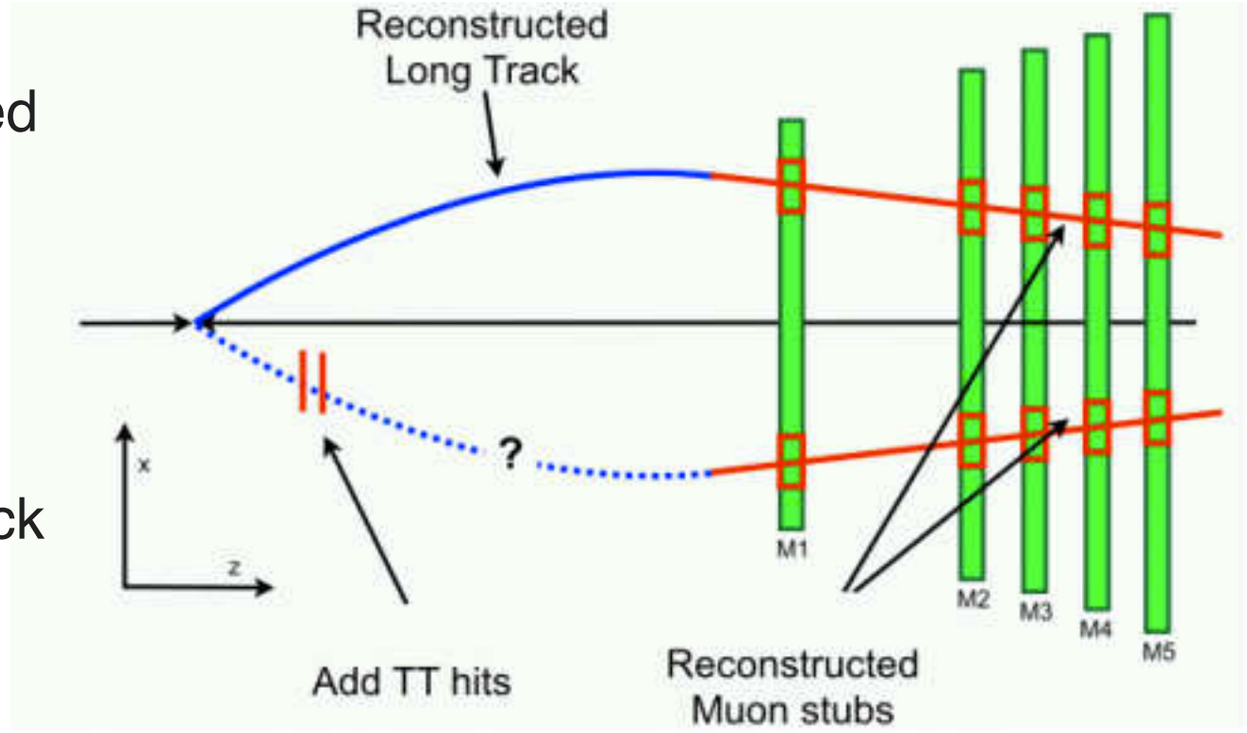


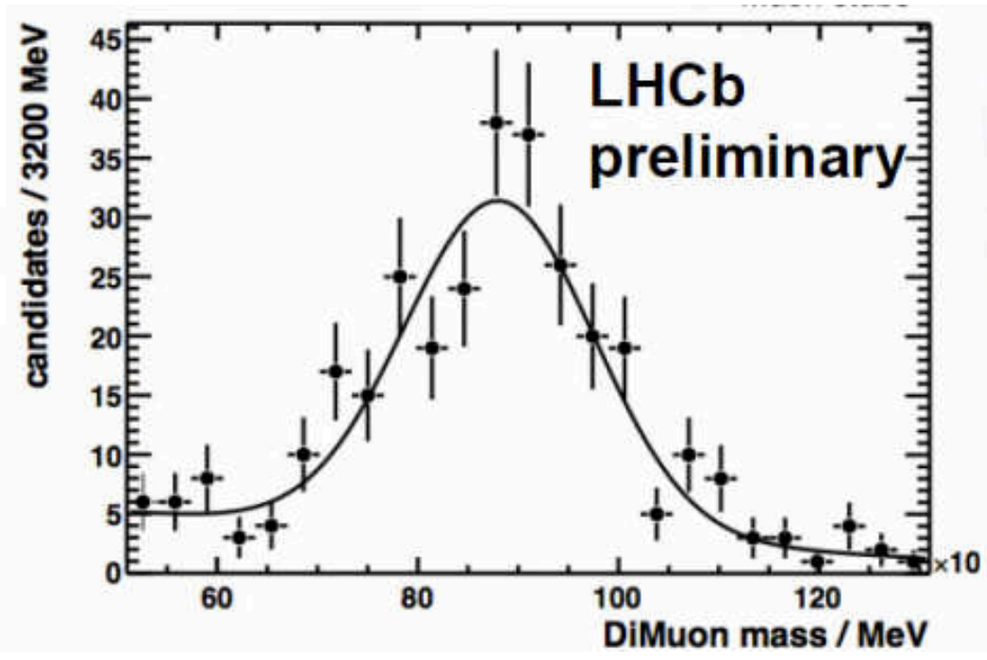
Tracking efficiency

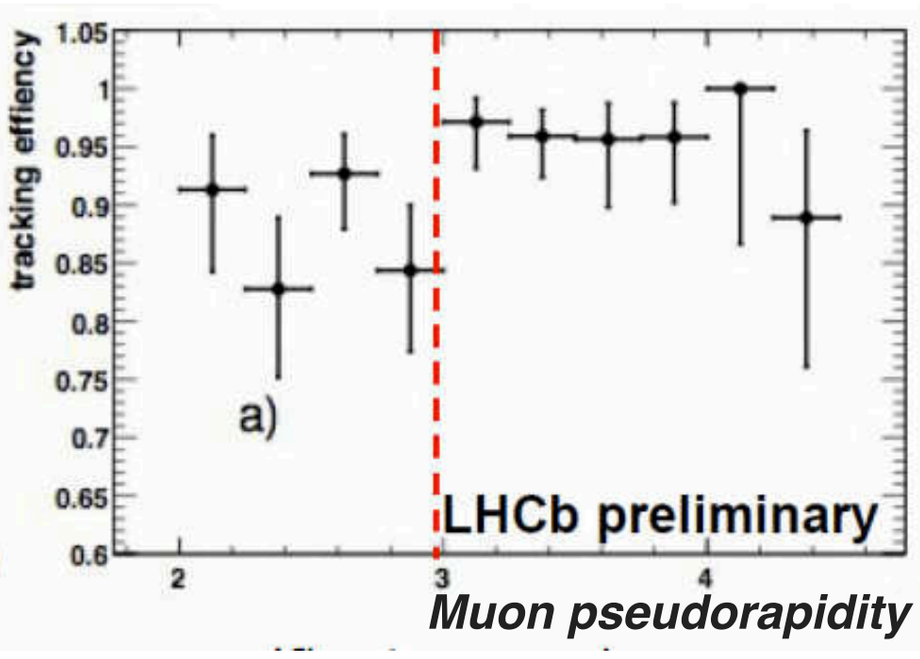
Single muon tracking efficiency

- Determine from data using an offline selected Z sample and tag and probe method
  Tag: long track muon passing trigger
  Probe: Muon stub with TT hits added
- Efficiency given by how often the probe can be matched to a reconstructed long track

Flat in Pt and phi, 2 regions considered in eta
No evidence of charge bias
eff = 93 ± 1 %





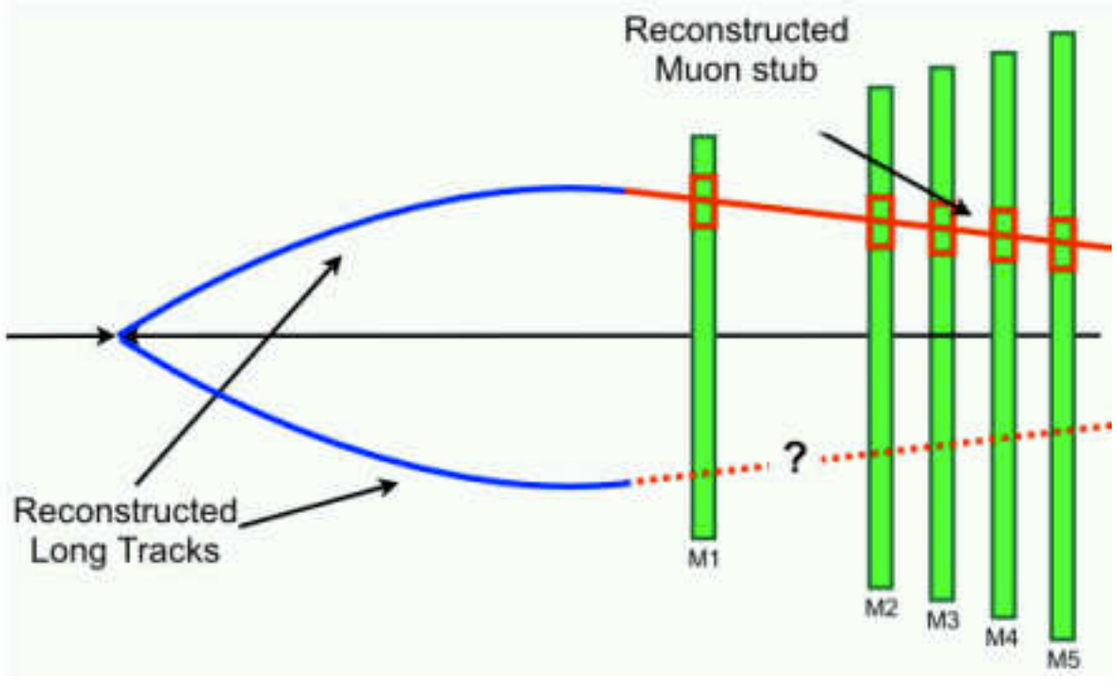


Muon ID efficiency

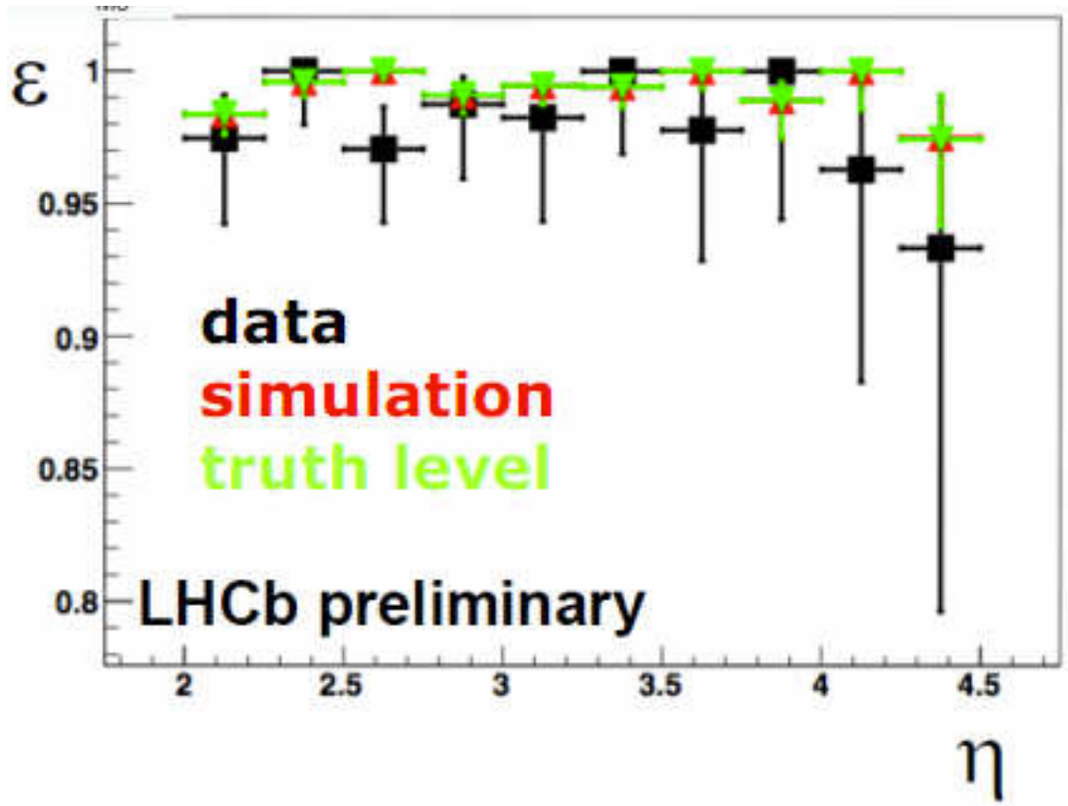
$$\varepsilon_Z = A_Z \varepsilon_Z^{trig} \varepsilon_Z^{track} \varepsilon_Z^{muon} \varepsilon_Z^{selection}$$

Single muon identification efficiency

- Determine from data using an offline selected Z sample and tag and probe method
  Tag: long track muon passing trigger
  Probe: Long track
- Efficiency given by how often the probe is identified as a muon



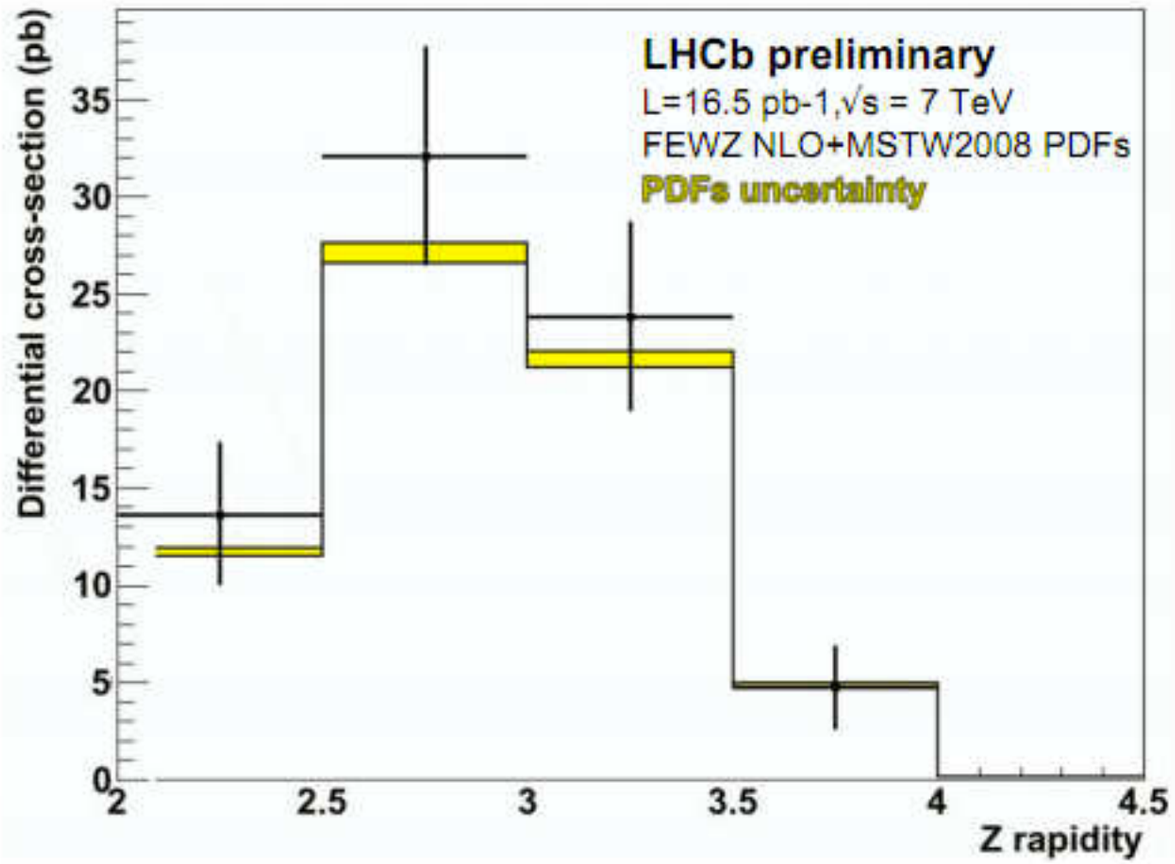
Flat in Pt, phi and eta
No evidence of charge bias
eff = 98.2 ± 0.5 %



Results: Z cross-section measurement

LHCb-CONF-2011-012

$$\sigma_{Z\to\mu^+\mu^-} = \frac{N^Z_{candidates} - N_{bg}}{\varepsilon^Z \cdot \int L}$$

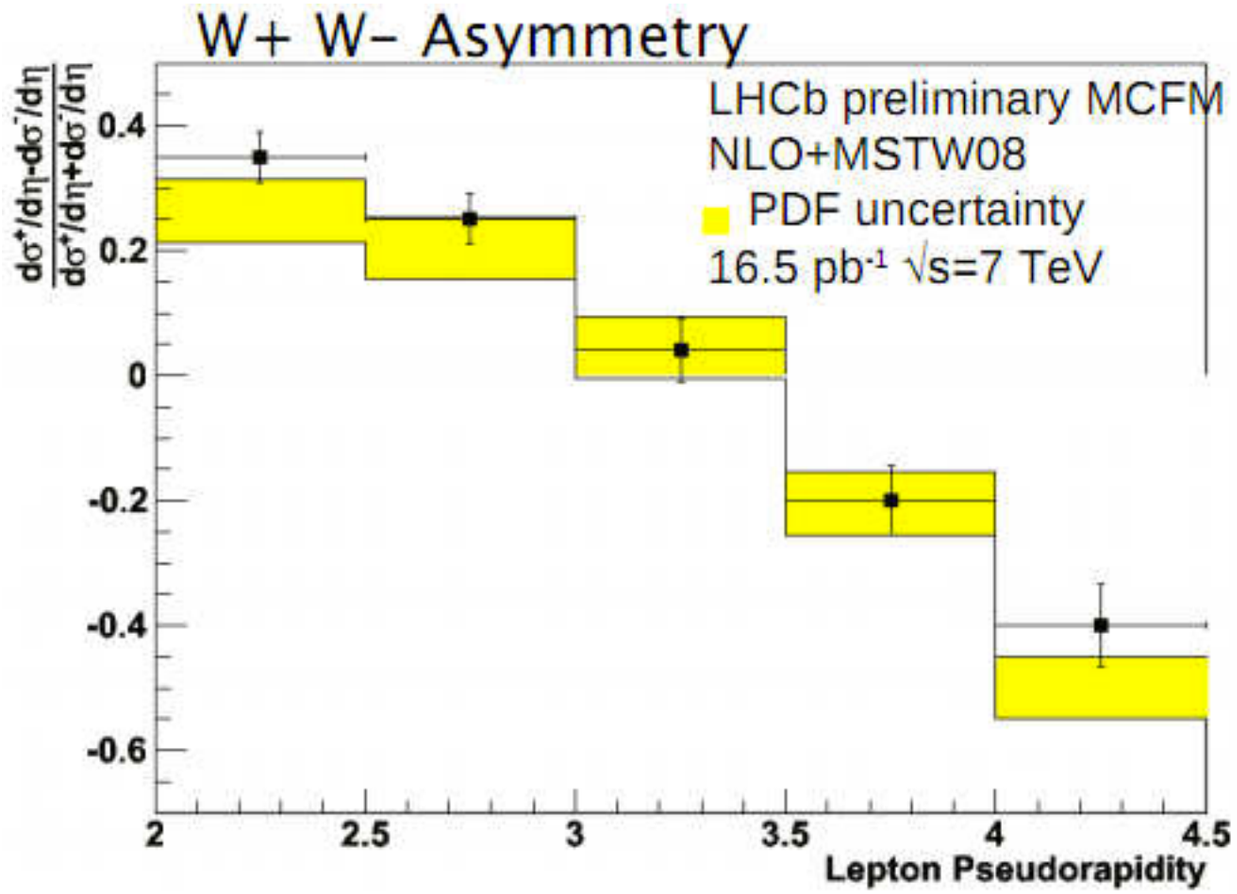


$2<\eta_\mu<4.5$, $81<M_{\mu\mu}<101$ GeV	
N_Z	833
N_{bkg}	1.2±1.2
ϵ_{trig}	0.86±0.01
ϵ_{track}	0.83±0.03
ϵ_{muon}	0.97±0.01
ϵ_{sel}	1.0
A	1.0
ϵ_Z	0.69±0.03
L	16.5±1.7 pb^{-1}
σ_Z	73±4±7pb

Results: W asymmetry measurement

LHCb-CONF-2011-012

$$A_{+-} = \frac{\sigma\left(W^+ \to \mu^+ \overline{\nu}_\mu\right) - \sigma\left(W^- \to \mu^- \nu_\mu\right)}{\sigma\left(W^+ \to \mu^+ \overline{\nu}_\mu\right) + \sigma\left(W^- \to \mu^- \nu_\mu\right)}$$



2<y<4.5	W+	W-
N_{Wcand}	7624	5723
W→τν	151	90
Z→ττ	2	2
Z→μμ	460	506
QCD	2194±150	1654±150
N_W	4817±165	3480±161
ϵ_{trig}	0.73±0.03	
ϵ_{track}	0.73±0.03	0.78±0.03
ϵ_{muon}	0.982±0.005	
ϵ_{sel}	0.55±0.01	
A	1.0	
ϵ_W	0.29±0.01	0.31±0.01
L pb $^{-1}$	16.5±1.7	
σ_W [pb]	1007±48±100	682±40±68

Summary of results

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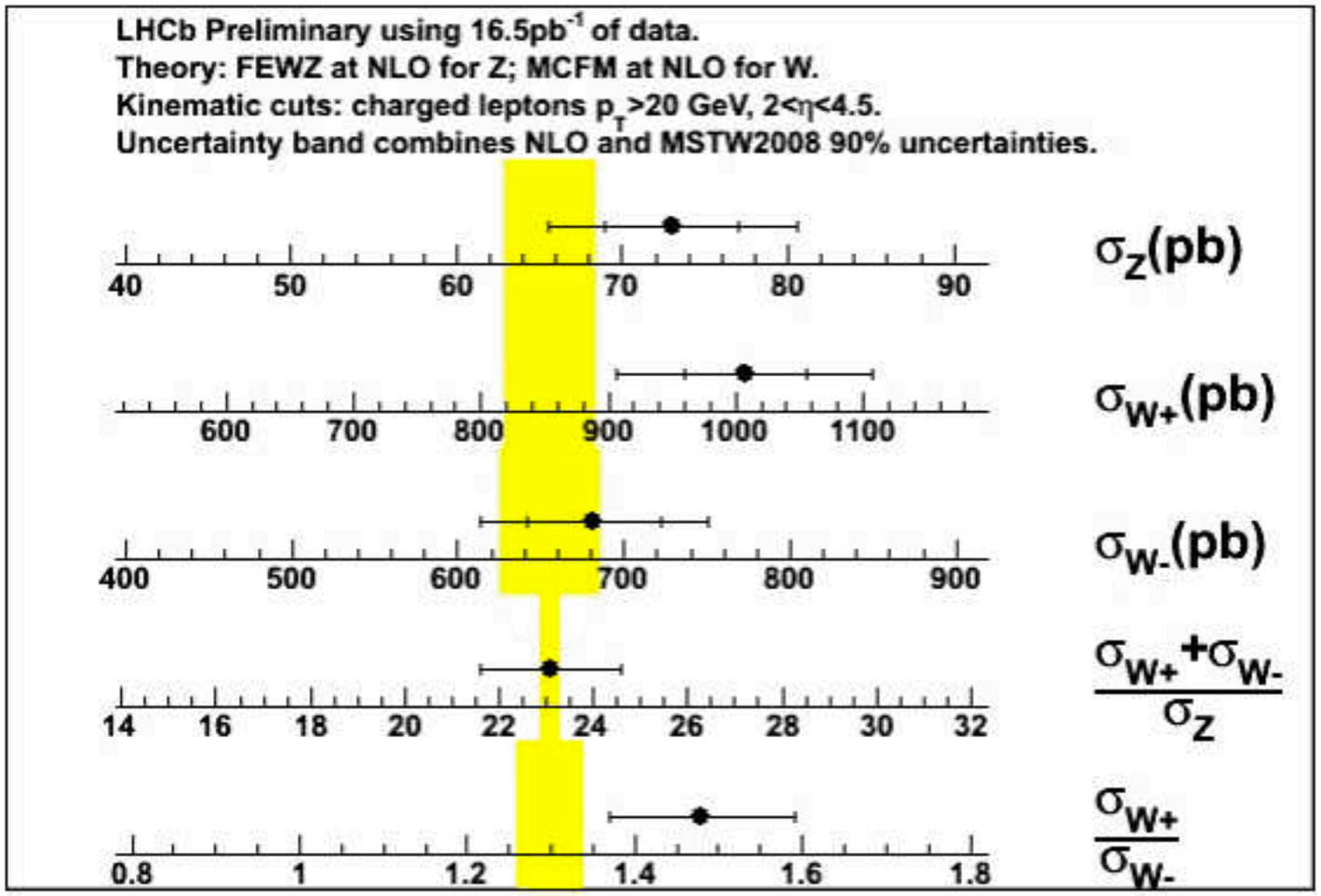
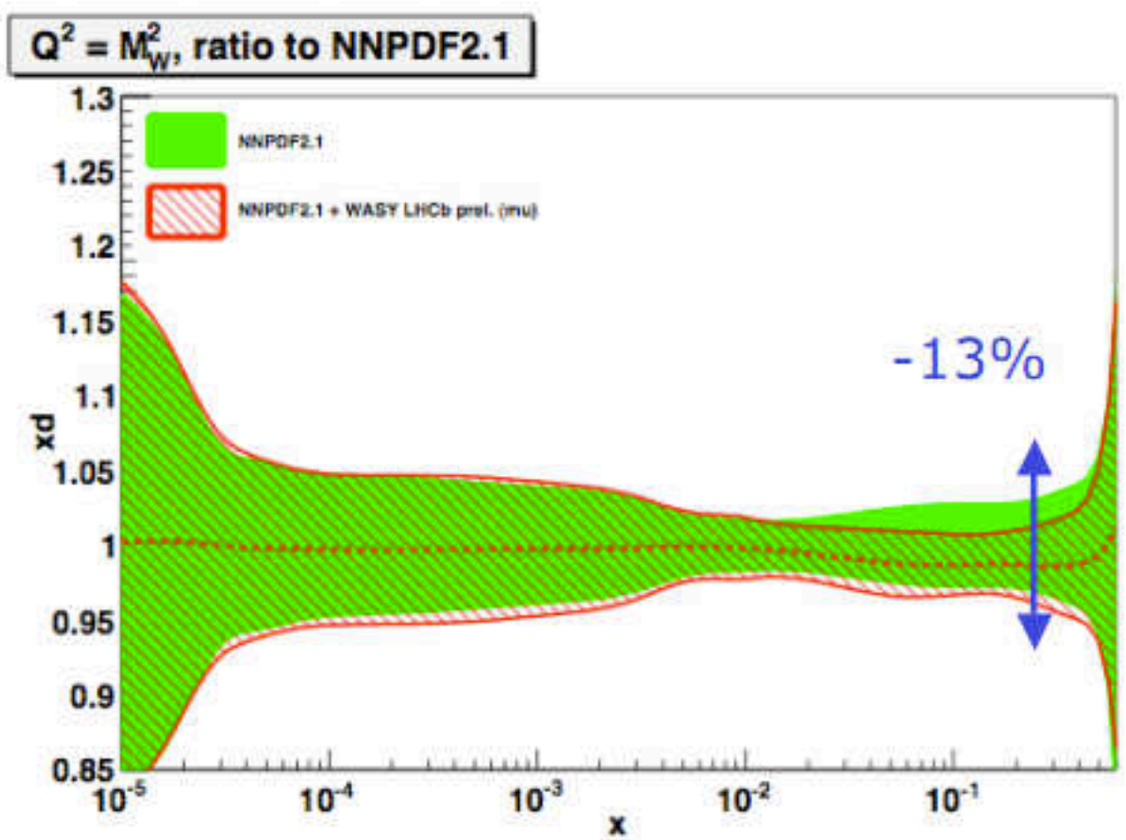
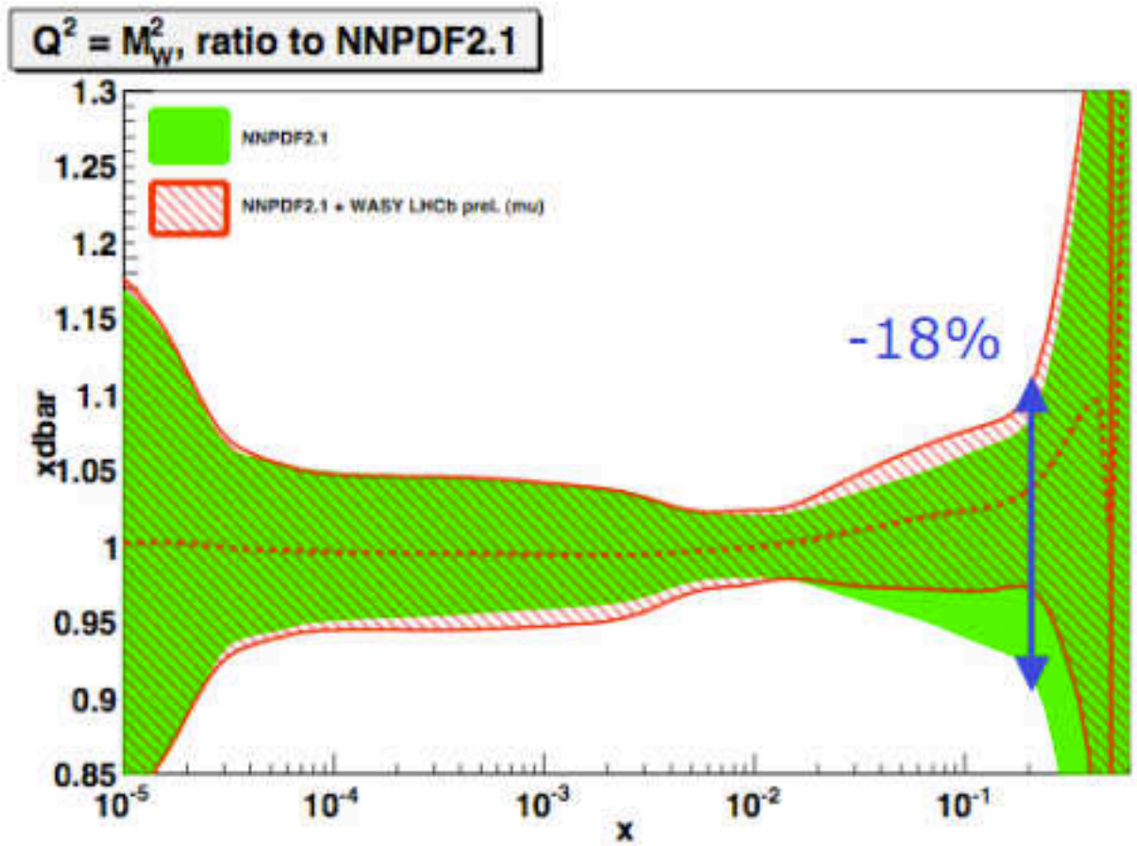
Compare results to MCFM NLO prediction (MSTW08)



All W,Z observations consistent with NLO predictions

Impact of W lepton asymmetry data from LHCb on PDF sets





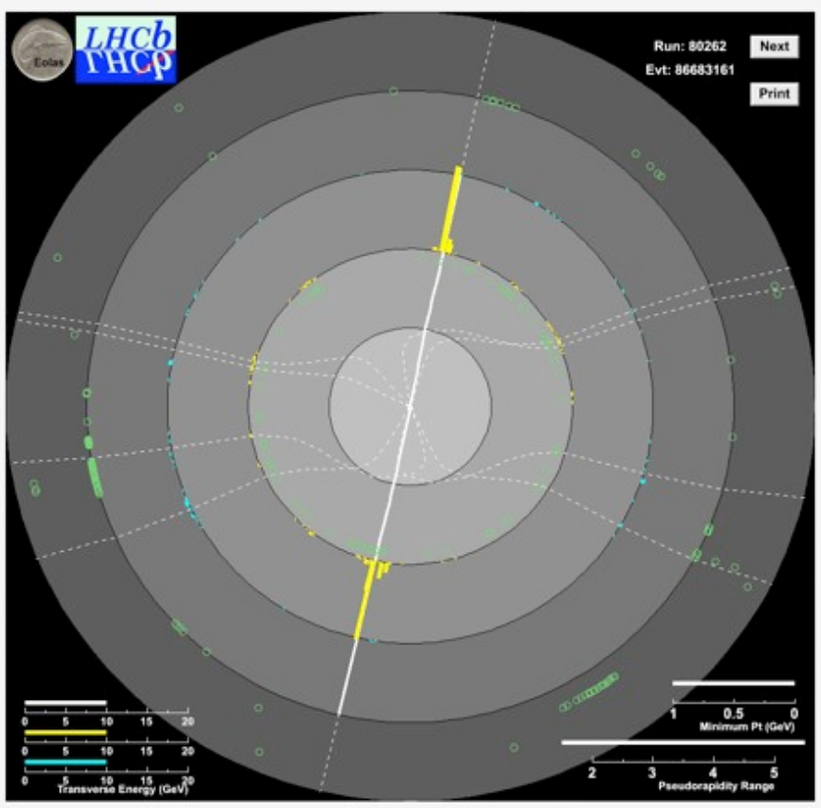
Slight reduction of uncertainty in the large-x region, small-x unchanged

From Maria Ubiali

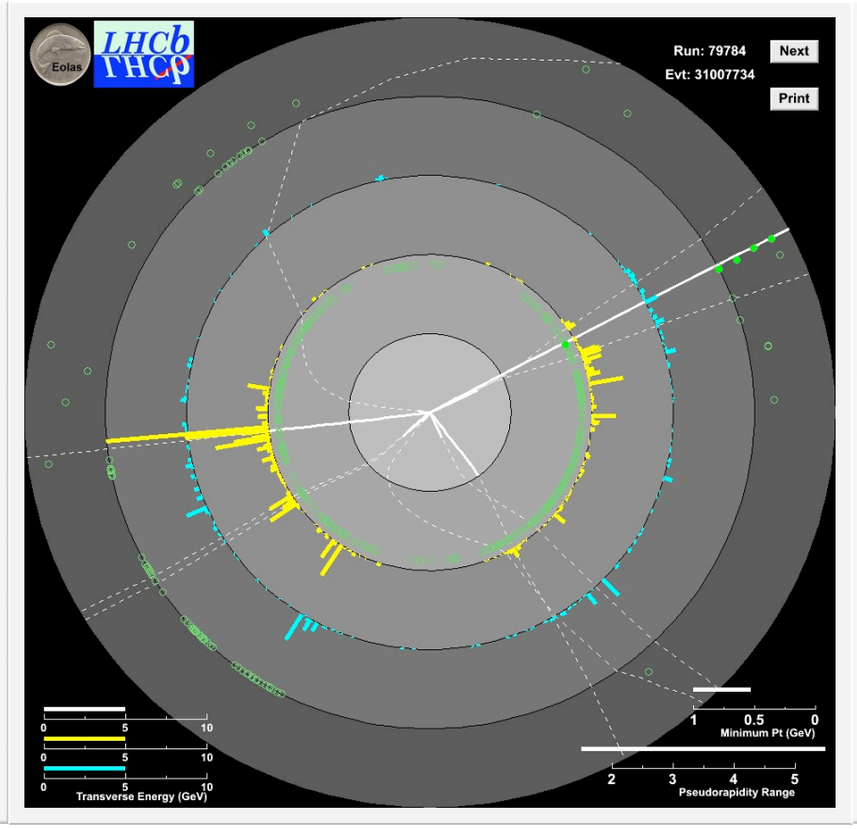
Other studies

- Work ongoing on other channels: W→eυ, Z→ee, Z→$\tau\tau$
- W & Z + jets: test pQCD, sensitivity to gluon PDF

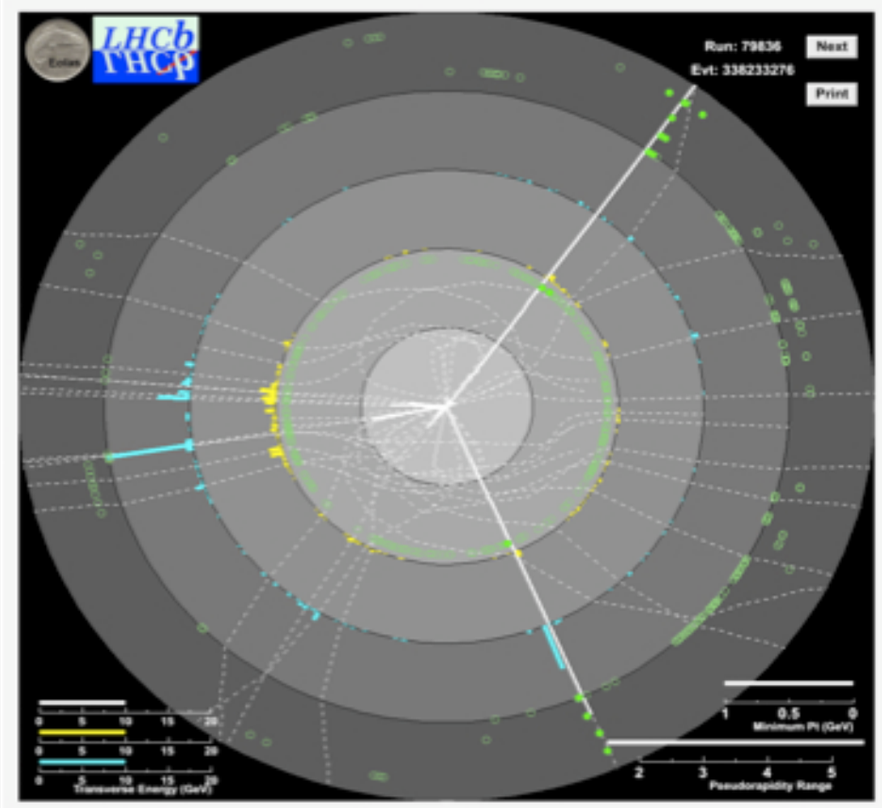
Z→ee



Z→$\tau\tau$→$\mu e\upsilon\upsilon\upsilon\upsilon$



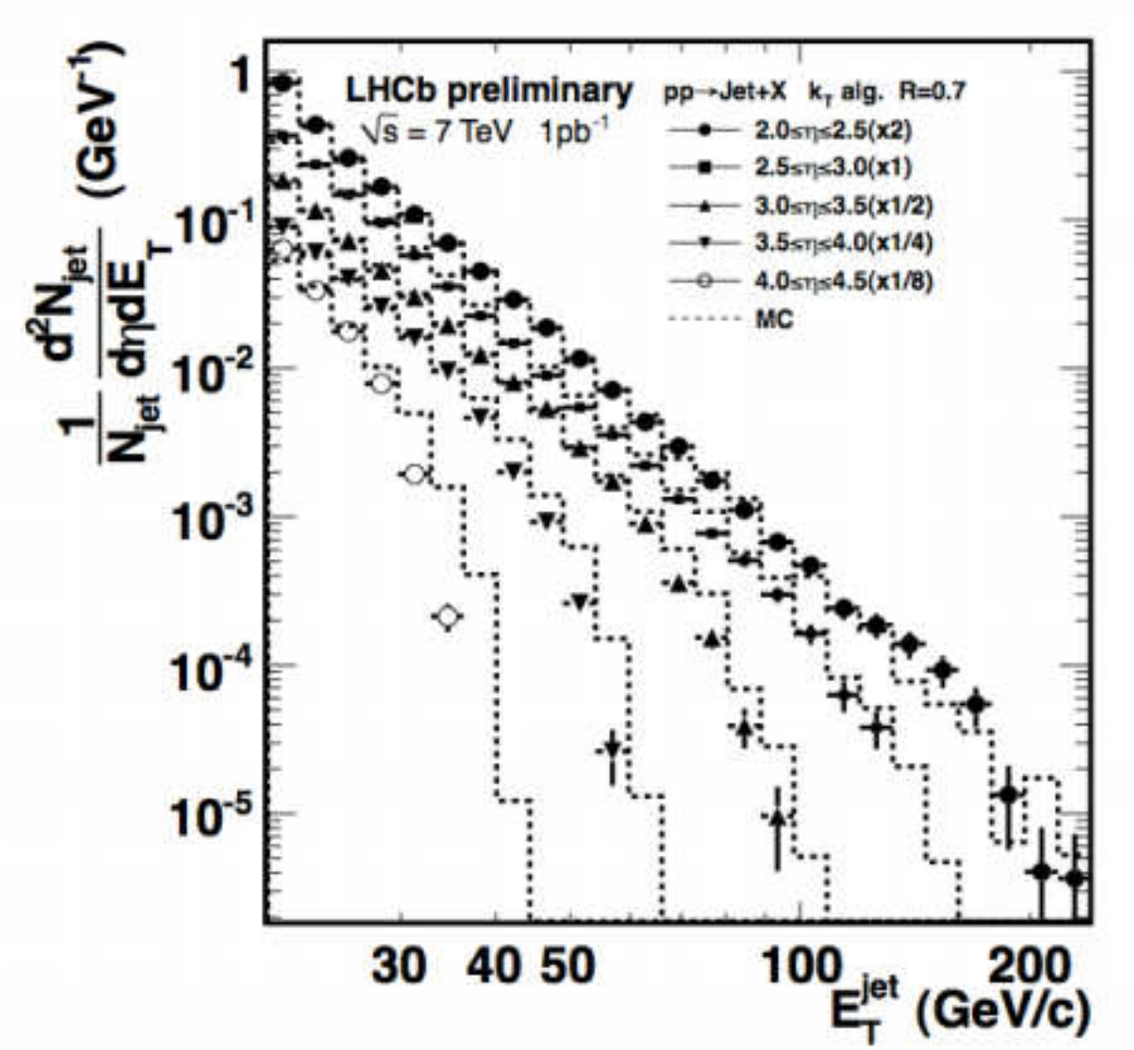
Z→$\mu\mu$ + jet



Towards W/Z + jets measurements

Work is currently ongoing towards measurements of W/Z + jet production at LHCb

Jet reconstruction is possible at LHCb - preliminary measurement of inclusive jet Et spectrum has already been made. Currently uncorrected for acceptance, jet energy scale and resolution (comparison with PYTHIA 6.4 below)



Conclusions

W and Z cross-section and ratio measurements

- Measurements complimentary to ATLAS/CMS
- Probe PDFs in previously unexplored region
- All W and Z measurements consistent with NLO predictions
- Luminosity uncertainty dominates for cross-section measurements
- W/Z ratio tests SM to 6%
- W lepton asymmetry data slightly reduces PDF uncertainty in high-x region

Outlook:

- Measurements will be performed again with much higher statistics from 2011 run
- Expect significant improvement in gluon PDF
- Measurements in electron and tauon channels
- W/Z + jet measurements